Reflection Mode Imaging with High Resolution X-ray Microscopy

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We report on the first demonstration of imaging microstructures with soft x-ray microscopy operating in reflection geometry. X-ray microscopy in reflection mode combines the high resolution available with x-ray optics, the ability to image thick samples, and to directly image surfaces and interfaces. Future experiments with this geometry will include tuning the incident angle to obtain depth resolution. In combination with XMCD as magnetic contrast mechanism this mode will allow studies of deep buried magnetic interfaces.

KEYWORDS: x-ray microscopy, reflection, surface, interface

1. Introduction

Transmission x-ray microscopy using zone plate optics has been widely used for high resolution imaging.[1)] In order to perform imaging with this method, the samples must be thin enough to transmit the incident radiation. Reflection mode imaging with x-ray microscopy eliminates the requirement for thin samples for transmission. We report on the first demonstration of imaging microstructures with soft x-ray microscopy operating in reflection geometry.

2. Experiment

The experiments were performed on the XM-1 microscope at the Advanced Light Source at Lawrence Berkeley National Laboratory. The sample was mounted with the incident illumination from the condenser lens at 7.5 degree incidence angle and the objective lens and CCD camera were rotated 15 degrees from the transmission geometry. A picture of the rotated system is shown in Figure 1. The sample was illuminated with 500 eV x-rays. The image formed from the reflected light was magnified by a zone plate onto a CCD.

The first samples were a W/B4C multilayer designed for high reflectivity for 500 eV radiation at 7.5 degree incidence angle. The sample was patterned with a FIB for high contrast test structures. The regions milled by the FIB have a lower reflectivity and appear darker in the image.

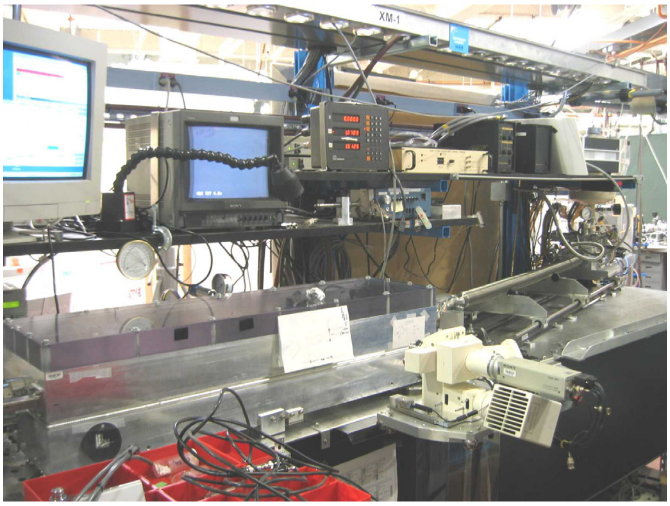

Fig. 1 Picture of the XM-1 microscope as used for reflection mode imaging. The objective lens and CCD camera were rotated 15 degrees from the standard transmission geometry.

2. Results

In transmission mode, this geometry would have provided a 12 by 12 micron field of view. With the shallow angle reflection geometry, the image is squeezed in one direction, so the resultant field of view was approximately 12 by 120 microns, but only approximately 12 by 3 microns was within the depth of focus.

One image as formed on the CCD is shown in Figure 2.

Fig. 2 X-ray microscop image in reflection mode of a test sample taken at 7.5 degree incidence angle. The dark regions have been milled by FIB to reduce the reflectivity. The image covers an area of approximately 10 microns vertically and 100 microns horizontally.

An image of the same region resized horizontally to represent equal scaling on the sample in each axis is shown in Figure 3.

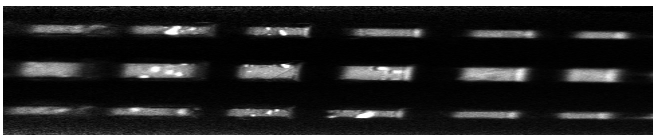

Fig. 3 X-ray microscope image of part of regions shown in Figure 2, rescaled to sample coordinates. This is a 12 by 72 micron region of the sample.

Of interest for the image in figure 3 is that the limited depth of focus of the zone plate optic used for imaging limits the lateral sample field of view in focus. For this image, it appears that properly focused field of view is approximately 12 microns vertically and 3 microns horizontally.

Another image of this sample is shown in Figure 4.

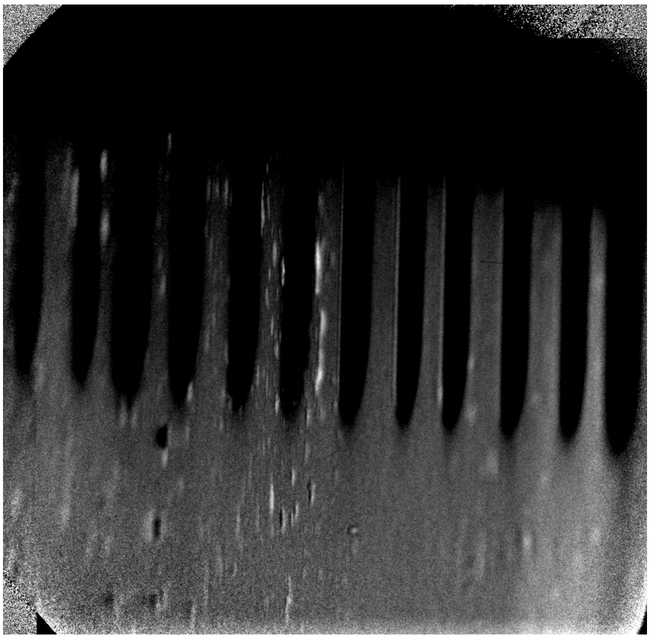

Fig. 4 Image of sample in reflection geometry as viewed on the CCD. The image region is approximately 12 microns vertically and 120 microns horizontally.

4. Conclusions

The first high resolution x-ray microscopy images in reflection mode were demonstrated. Future experiments with this geometry will include tuning the incident angle to obtain depth resolution in grazing incidence geometry. In combination with XMCD as magnetic contrast mechanism this mode will allow studies of deep buried magnetic interfaces with respect to the local variation of magnetic roughnesses and to obtain a magnetization depth profile with lateral resolution. This will provide important information to characterize the magnetization behaviour at interfaces.

Acknowledgments

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